Fifth Annual Conference on Carbon Capture & Sequestration

Steps Toward Deployment

Conference Poster

Case Studies of CO_2 Capture Retrofitting in Existing Coal-Fired Power Plants

Yongqi Lu [1], Shiaoguo Chen [2], Massoud Rostam-Abadi [1,2], Jose D. Figueroa [3]

[1] University of Illinois at Urbana Champaign
[2] Illinois State Geological Survey
[3] US DOE/ National Energy Technology Laboratory

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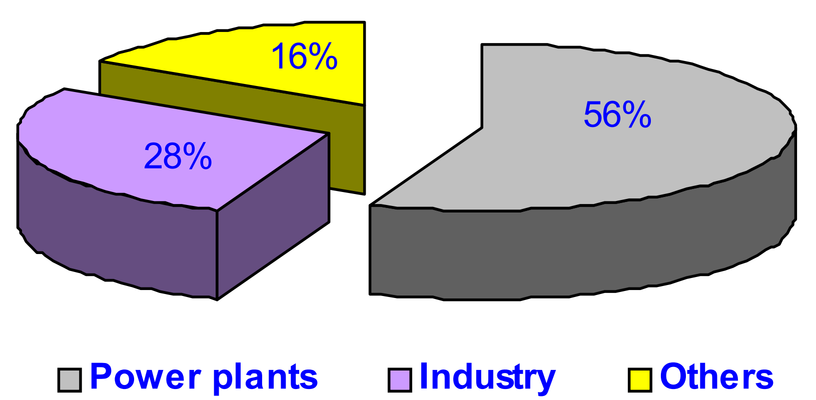
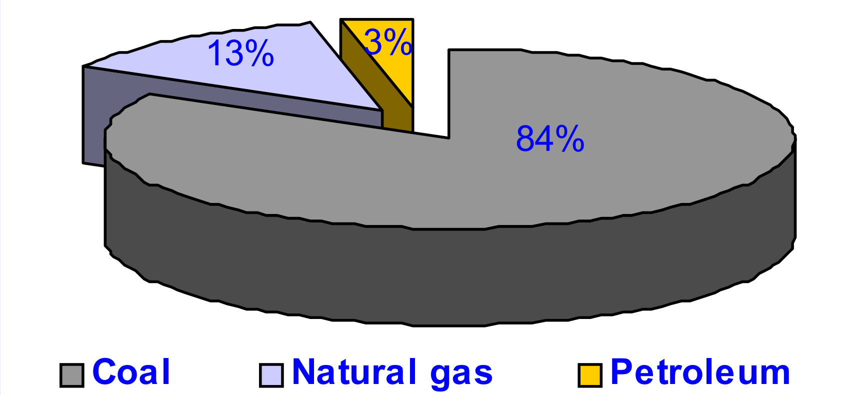
Introduction

- *US coal-fired power plants total capacity = 300 GW*
- *Coal-fired plants responsible for about 50% of the US total stationary CO_2 emissions.*
- *Most existing coal-fired power plants will be in operation for several decades.*
- *The mono-ethanol-amine (MEA) absorption process is a commercially available technology for CO_2 capture from the PC steam power plant*
- *The MEA process consumes ~30% of electricity output. An auxiliary power generation unit is required to compensate for the electricity loss.*

Stationary CO_2 emissions



CO_2 emissions from power plants



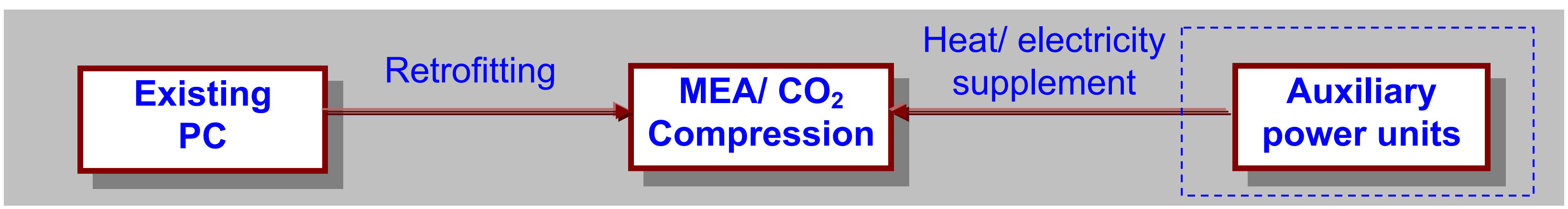
Objective of Case Studies

- *Assess the techno-economic performances of MEA retrofitting plants equipped with different auxiliary heat/electricity supply units.*

- *Case studies*
  - *Different process configurations*
  - *Fuel type (gas and coal)*
  - *Impact of fuel price*
  - *Impact of retrofitting plant scale*

Description of Cases for Heat/Electricity Supplement

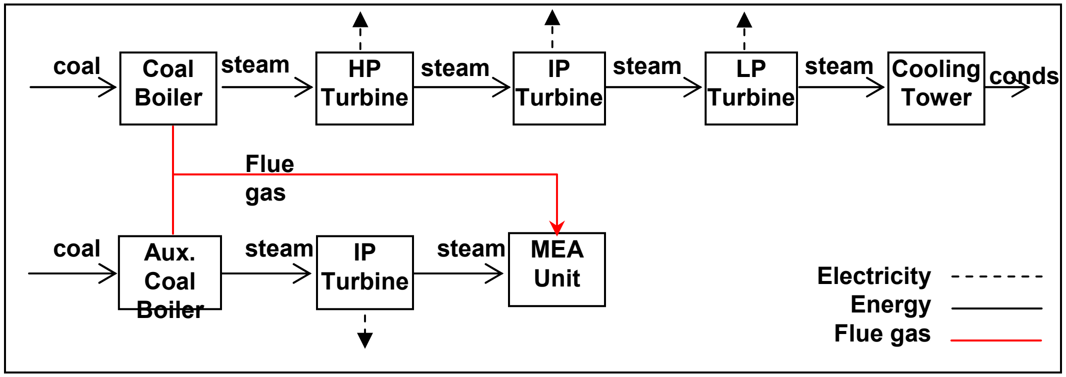
- Case A: Coal-fired IP steam boiler + IP turbine
- Case B: Natural gas (NG) combustion turbine (GC) + NG low pressure (LP) steam boiler
- Case C: Regular coal-fired plant
- Case C-1: “Purchasing” coal electricity and no auxiliary power unit
- Case D: Regular NGCC plant
- Case D-1: “Purchasing” NG electricity and no auxiliary power unit



Case studies

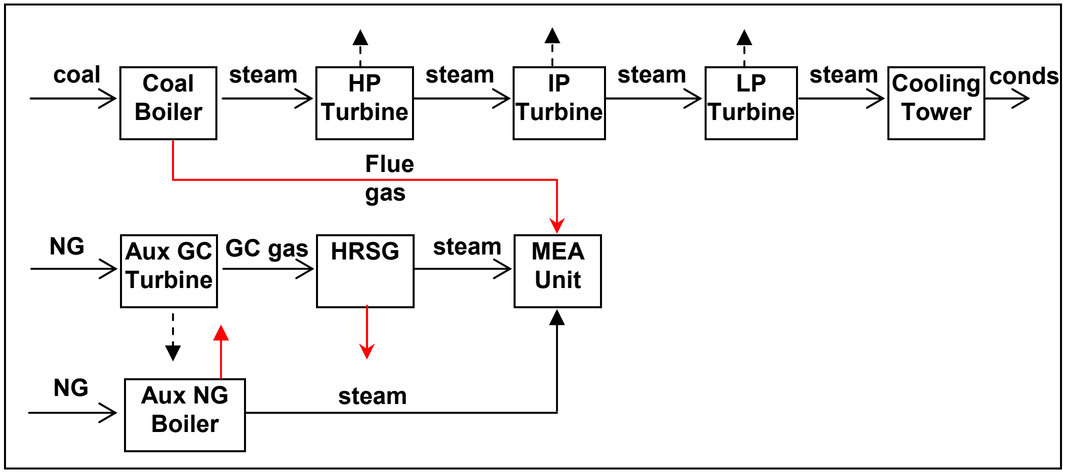
Case A: Coal-fired IP steam boiler + IP turbine

- *Supply all steam*



Case B: Natural gas (NG) combustion turbine (GC) + NG low pressure (LP) steam boiler

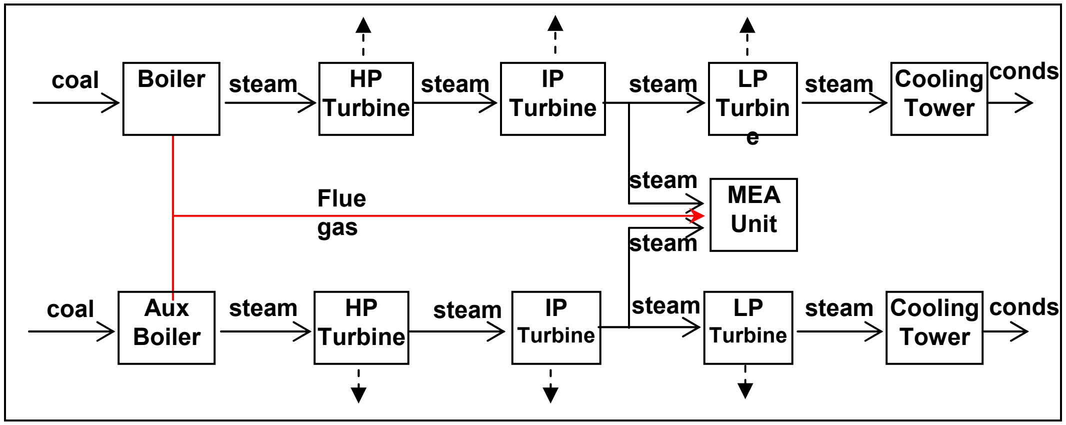
- *Supply all steam*
- *CO_2 from NG combustion not captured*



Case C: Regular coal-fired plant

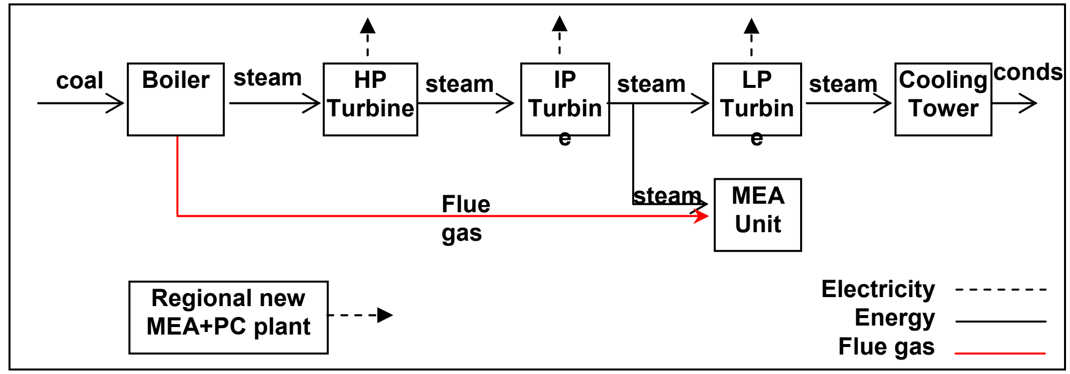
- *Supply part of steam*

(steam supply proportional to the aux. scale)



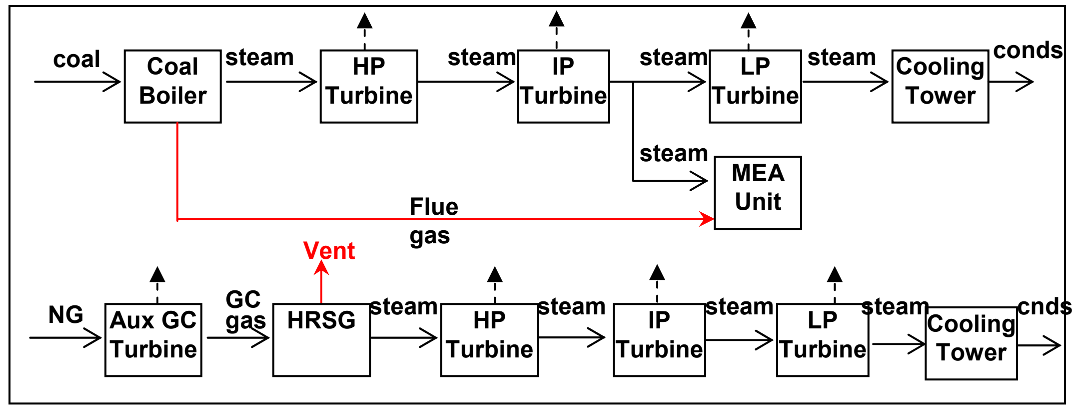
Case C-1: Purchasing" coal electricity and no auxiliary power unit

- No auxiliary unit on-site
- New coal-fired power plant



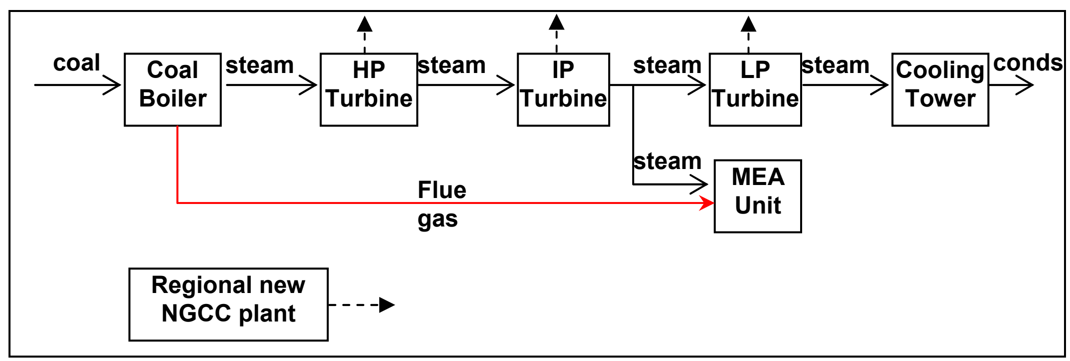
Case D: Regular NGCC plant

- Supply no steam, electricity only
- CO_2 from NG combustion not captured



Case D-1: Purchasing" NG electricity and no auxiliary power unit

- No auxiliary unit on-site
- New NGCC plant



Methodology

- *Process simulation*
  - *Chemcad process simulation software employed to perform steady-state simulations for mass and energy balances of the process*
  - *Modeling includes combustion, steam cycle, flue gas cleaning, and CO_2 capture for power plant and auxiliary unit*
  - *Information related to equipment sizing, commodity consumption, and in-plant power use obtained from the simulation*

- *Cost modeling*
  - *DOE Guideline for Techno-Economic Analysis and EPRI Technical Assessment Guide (TAG) methodology followed*
  - *Equipment cost scaled from recent DOE, EPRI, EPA studies*

Major Assumptions

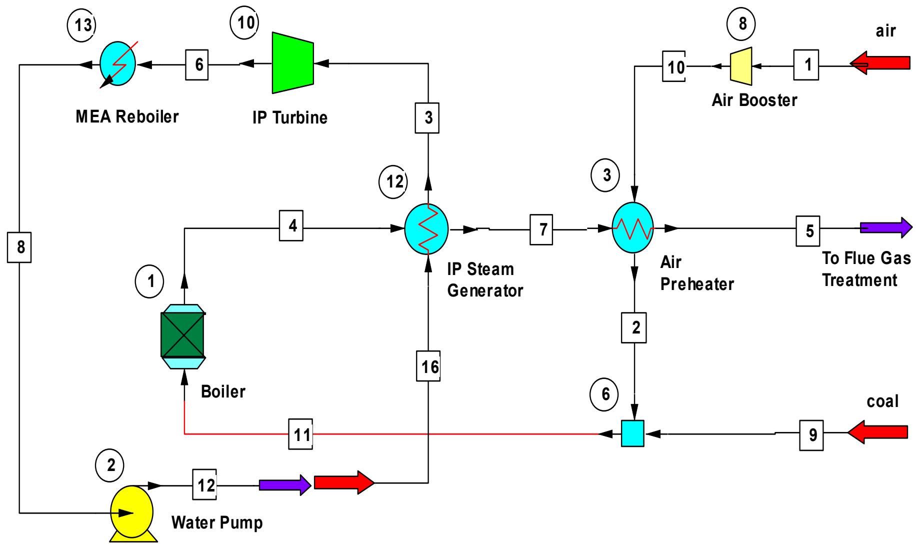
- Baseline PC Power Plant
  - PC plant based on single reheat sub-critical steam power cycles
  - Illinois No.6 coal burned at a 15 vol% excess air
  - Net electricity efficiency of 37.8%
  - Electricity output 533 MWe (Gross)

- Baseline fuel price
  - Coal = $30/ton
  - NG = $6/mmBTU

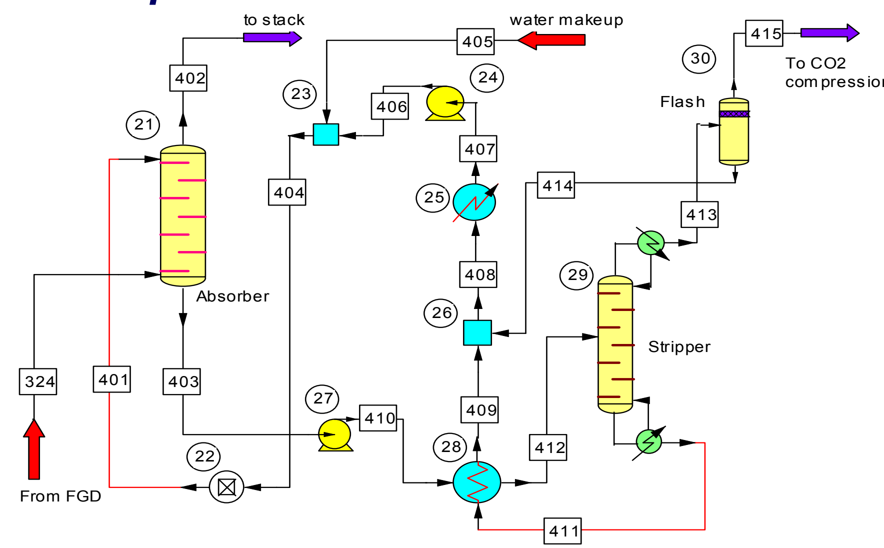
- MEA process
  - Fluor Daniel Econamine FG process
  - Stripping steam extracted from LP turbine at 60 psi
  - CO_2 capture efficiency of 90%

An Example of Case A: Coal-fired IP steam boiler + IP turbine

Auxiliary power unit



MEA process



Overall perform.	Auxiliary unit	Existing plant
Coal feed, lb/hr	240,888	360,611
Air feed, lb/hr	2,666,121	3,991,198
MEA heat duty, MJ/h	2,461,242	
Steam turbine power generation, MWe	105.4	533.2
CO_2 compress. and MEA auxiliary, MWe	85.6	
Other auxiliary power, MWe	19.5	34.7
Net electricity, MWe	0.3	498.5
Net efficiency (HHV), %	22.7%	
Net heat rate (HHV), Btu/kWh	15,053	
CO_2 captured, lb/hr	1,391,627	

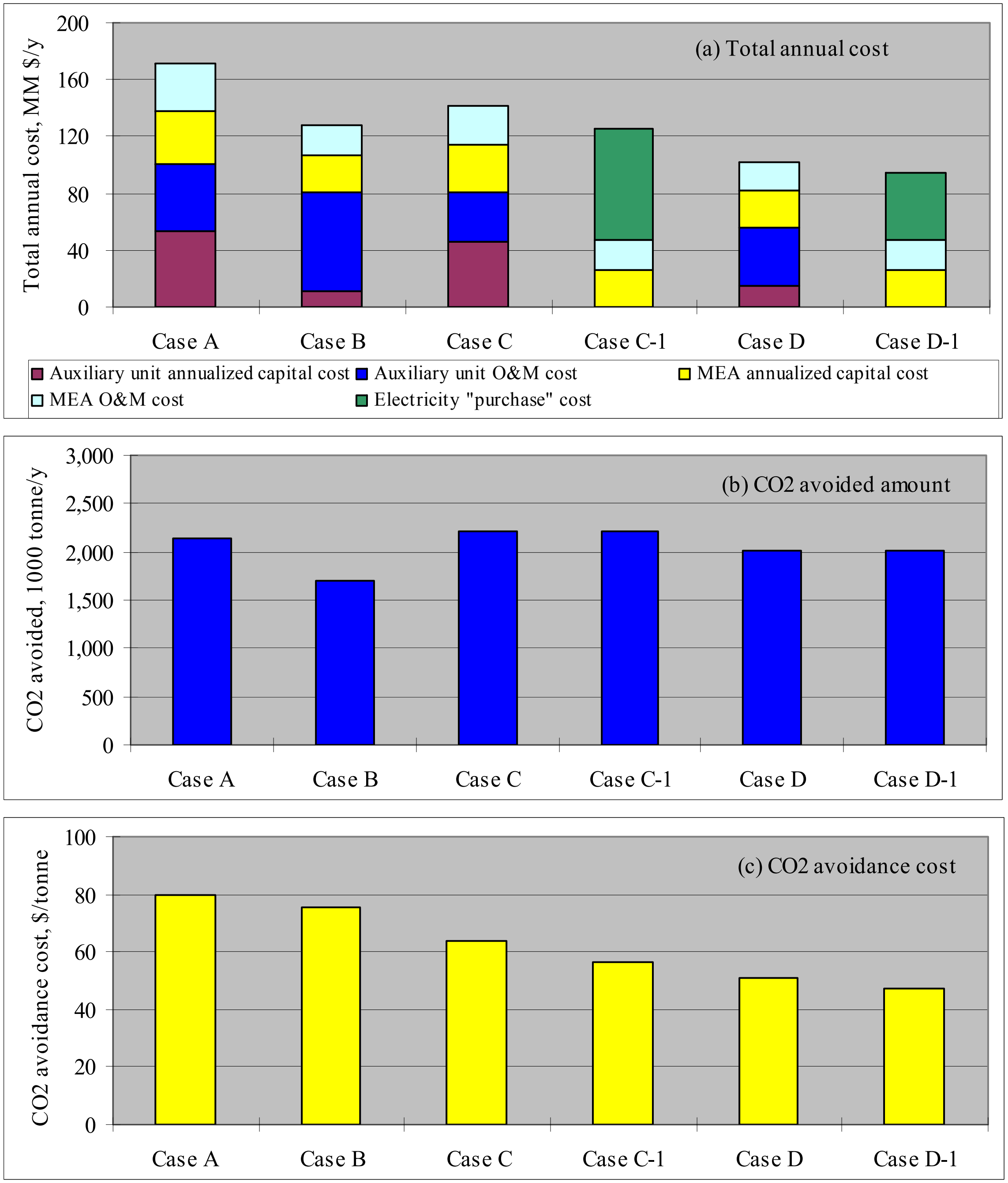
Cost	Auxiliary unit	MEA unit
Total plant post (TPC), k$	309,189	213,134
Total capital requirement (TCR), k$	356,158	247,028
Levelized capital cost, k$/y	53,958	37,425
Fixed O&M, k$/y	18,717	6,879
Variable O&M, k$/y	28,078	26,379
Total annual cost, k$/y	100,753	70,683
Net CO2 avoided, k tonne/y	2,320-173 *	
Cost of CO_2 avoidance, $/tonne	79.84	
Increase of electricity cost, mills/kWh	56.05	

Results of Case Studies

- **Coal-fired Case A, C and C-1**
  - Case A is the most expensive
  - Case C-1 which "purchases" electricity from off-site large plants is the most economical

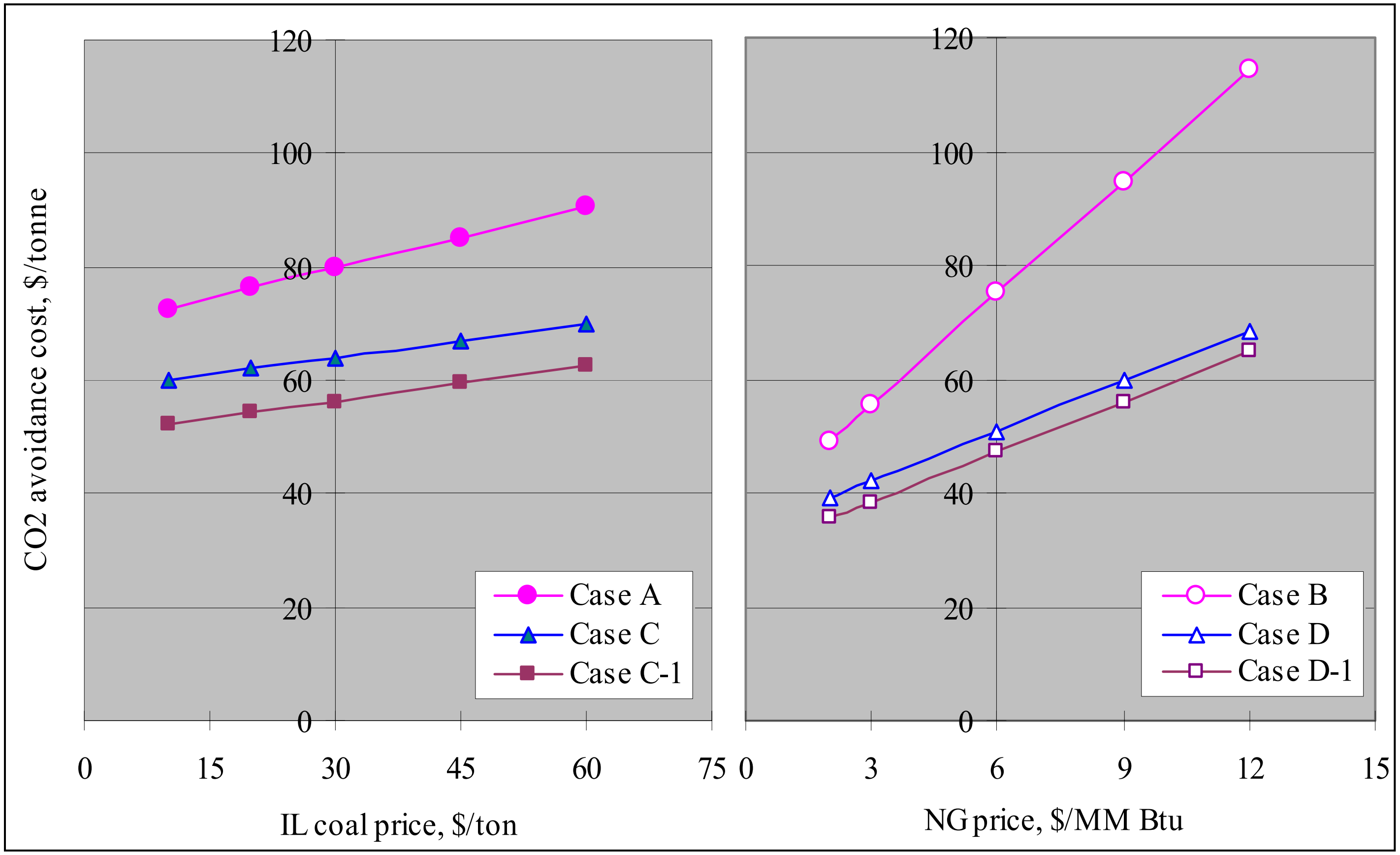
- **NG-fired Case B, D and D-1**
  - Case B is the most expensive because of lower overall efficiency of energy use

- At prices of $30/ton coal and $6/MMBtu NG, retrofitting with NG is more cost effective

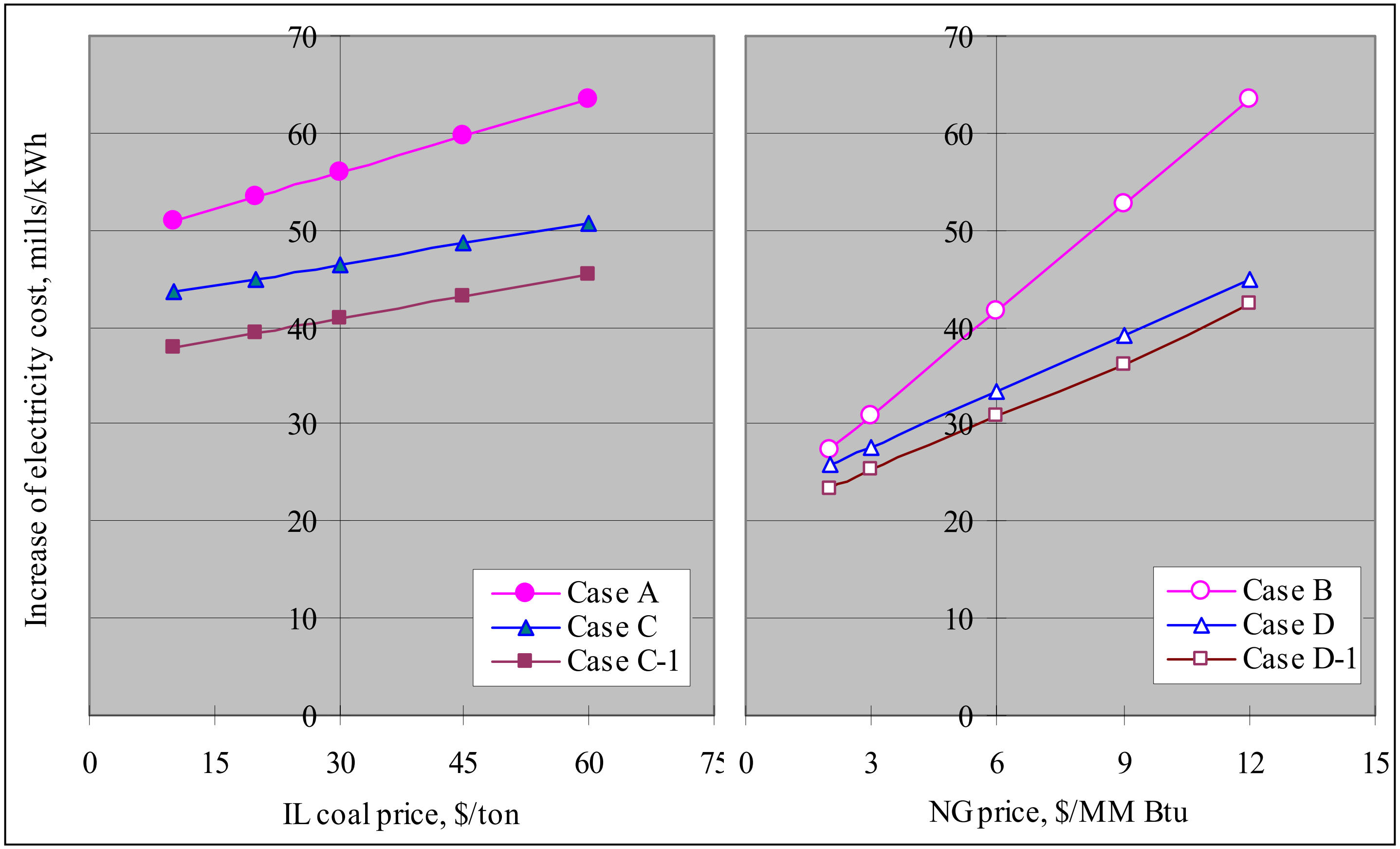


Case A: Coal boiler/IP turbine; Case B: NG LP steam boiler + GC turbine; Case C: Coal-fired power plant; Case C-1: "Purchasing" coal electricity; Case D: NGCC plant; Case D-1: "Purchasing" NG electricity

Sensitivity of Fuel Price

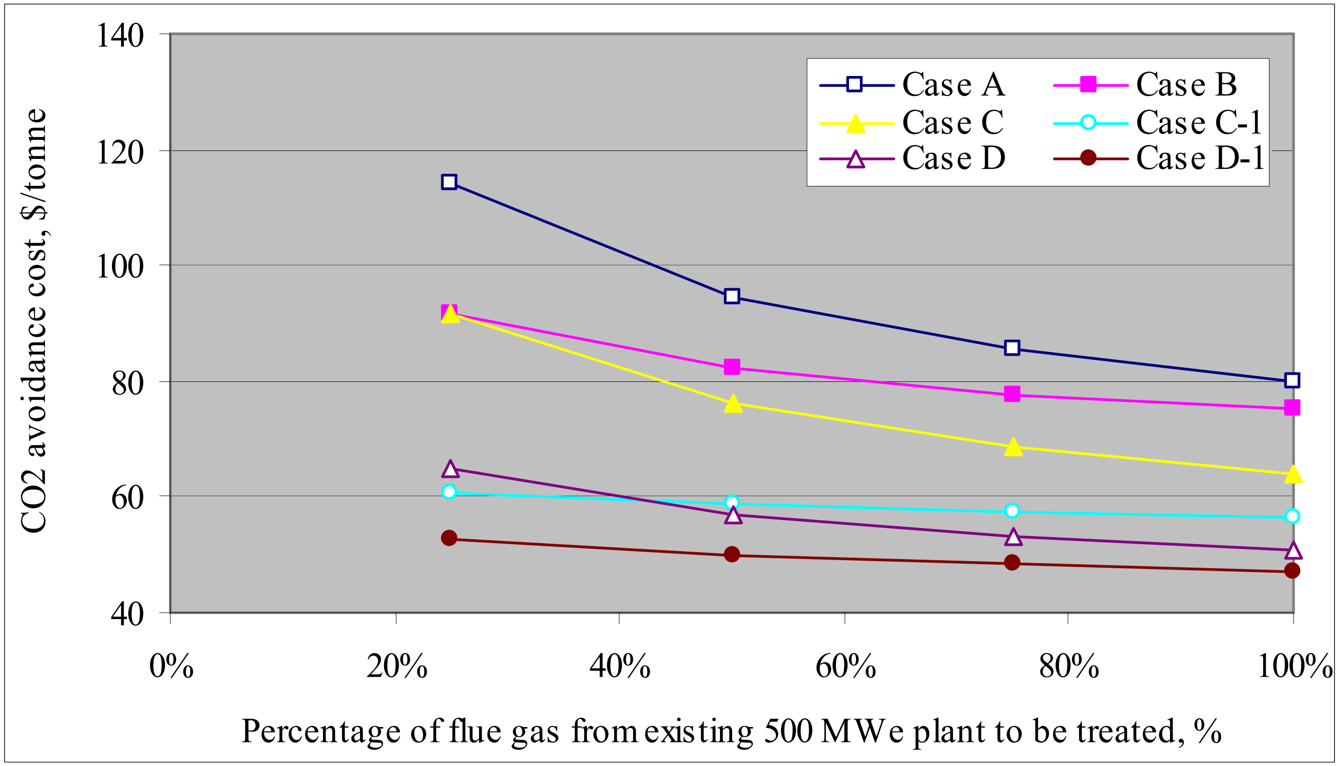


- Case A and Case B: If NG price > $7/MM Btu, Case A is more economically favorable.
- Case C and Case D: At NG price > $10/MMBtu, the coal-fired auxiliary unit and the NG-fired unit have comparable costs.
- Case C-1 and Case D-1: At NG price > $10/MM Btu, the coal-fired Case C-1 is competitive to the NG-fired Case D-1.

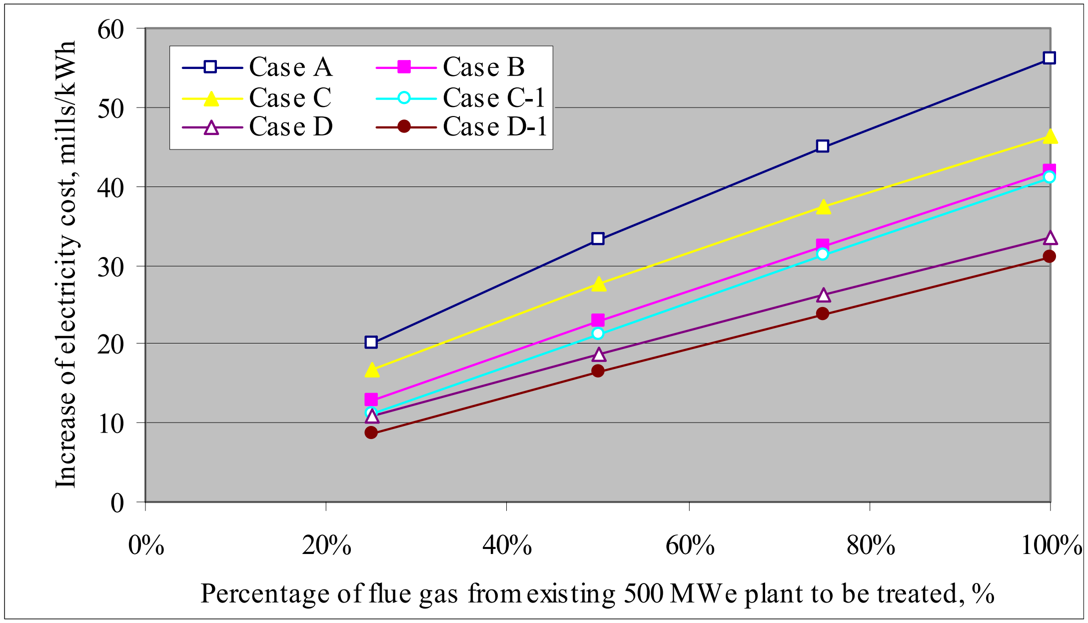


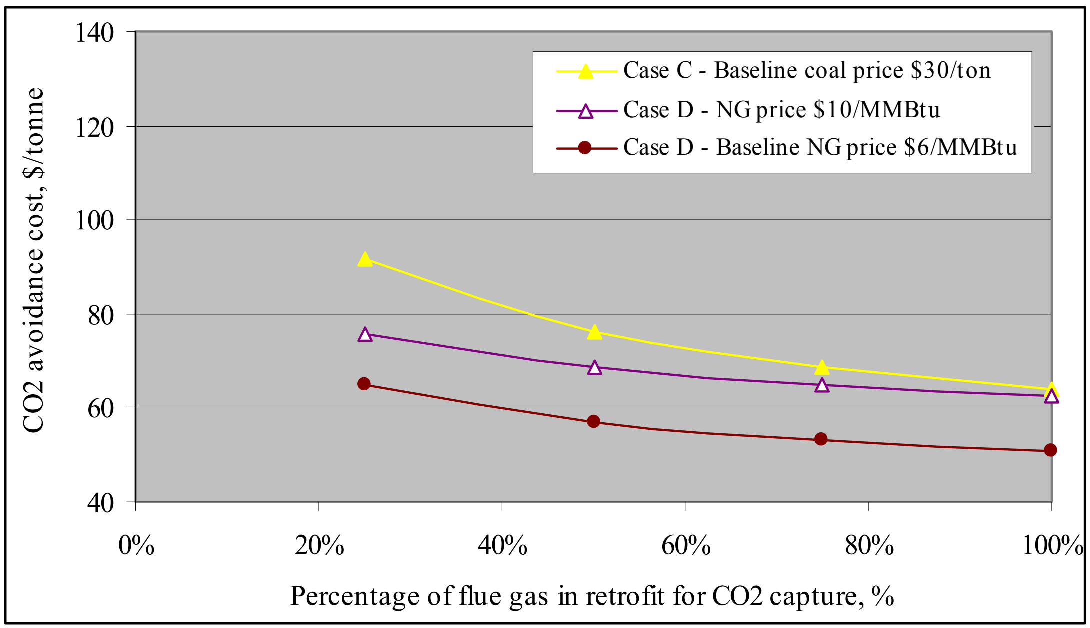
- *Increase of COE for the NG-fired auxiliary unit is lower than its coal-fired counterpart. However, because CO_2 emissions from NG-fired auxiliary unit is not captured, more CO_2 are emitted. If NG-CO_2 is to be captured, its COE will significantly increase.*
- *For retrofitting with NG-fired auxiliary units, the O&M cost, mainly due to the NG cost, is a major part of the total cost. As a result, the cost sensitivity to the NG price is much more significant than to the coal price*

Sensitivity of Power Plant Scale



- *CO_2 avoidance cost increases with decreasing percentage of flue gas treatment in all cases*
- *Cases B and D are less sensitive to the scale than Cases A and C. Because flue gas from NG-fired Cases B and D is not treated for CO_2 capture, the impact of the MEA plant scale for Cases B and D is less than the coal-fired cases.*





- *Almost linear decrease of the electricity cost with CO_2 capture scale*
- *At NG price of $6/MMBtu, Case D has lower CO_2 avoidance cost than its coal counterpart Case C for different scales examined. At NG price of $10/MMBtu, and when only a fraction of the flue gas is treated, the costs in Case D are still lower than those in Case C.*

Summary

- *Installing an auxiliary power unit to provide steam required by MEA regeneration (Case A and Case B) is neither energy-efficient nor economic*
- *An auxiliary unit employing a standard coal-fired PC or NGCC plant (Case C and Case D) can improve the overall economics of CO_2 capture. Part of steam required for MEA regeneration needs be drawn from the existing power plant.*
- *The most economic option is to build new large power plants to offset the electricity loss in regional retrofitting without building small auxiliary power units on individual retrofitting sites (cases C-1 and Case D-1).*
- *Overall, if the NG price > $9-10/MM Btu, and the coal price is at $30/ton, retrofitting with coal-fired auxiliary units could be economically competitive to NG-fired auxiliary units.*
- *CO_2 capture for NG combustion was not included in this study. However, capturing CO_2 from NG combustion is more expensive than the CO_2 from coal combustion.*
- *Reducing the volume of the flue gas to be treated from 100% to 25% will increase the CO_2 avoidance cost by 10-45%, depending on the retrofitting configuration.*